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Displaced Orbital Fractures with Concurrent Orbital Compartment Syndrome: A Case-Based Systematic Review

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Abstract

Orbital compartment syndrome (OCS) is an emergency that complicates intra-orbital, retrobulbar hemorrhage in most cases. Bony orbital decompression is an effective treatment for OCS, and displaced orbital fractures are protective. Nevertheless, in rare cases, OCS occurs despite a displaced orbital fracture. The aim of the current review is to present its pathophysiology and management based on what is published in the medical literature, and our center's experience. A systematic review of literature was conducted through PubMed, Medline, Embase, and Cochrane from inception through February 2021. The following search query was used: "orbital fracture" and "trauma" and "orbital compartment syndrome." Studies tackling the pathophysiology and management of concurrent displaced orbital fracture with OCS were included and a cohort of patients was constituted. A cohort of 18 cases reported in the literature were included (49.3 ± 30.6 years, 50% M). Given that OCS occurs with or without orbital fracture, pathophysiology of OCS is mostly explained by the division of the orbital fat into many compartments, due to the presence of Koorneef's fibrous septa. Management of OCS in such circumstances consisted of inferior-lateral canthotomy and cantholysis in 50% of cases, subperiosteal drainage with myringotomy in 22.2% of cases, subperiosteal drainage in 16.7% of cases, and complete lateral cantholysis in 16.7% of cases. Two cases who presented to our tertiary care center were also added to this review. Physicians should be aware that OCS can occur even with displaced fractures of the orbital cavity. When clinical suspicion is present, an emergent management is needed.

Keywords

- orbital compartment syndrome
- orbital fracture
- canthotomy
- cantholysis
- trauma

Orbital compartment syndrome (OCS) is a rare sight-threatening emergency that should be promptly recognized and treated within 2 hours. It presents most commonly after an acute intra-orbital, retrobulbar hemorrhage.[1] In the absence of treatment, the rapid increase in compartment pressure causes mechanical stretching, compression, and ischemic damage to the optic nerve and/or a central retinal arterial occlusion and may lead to irreversible loss of sight.[2,3] The total orbital volume is approximately 30 mL, concurrently, any increase in the intra-orbital volume will raise the compartment's pressure due to the firm attachments of the eyelids to the orbital rim mainly by means of the canthal ligaments and to the rigid pyramidal structure of the bony orbit.[1,4]

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OCS can occur after orbital/maxilla-facial surgery or trauma, orbital tumors,[1,5] retrobulbar injections,[6] with anticoagulant/thrombolytic drugs[7] and even spontaneously.[1] The canthotomy and cantholysis is an indispensable tool in an emergency physician's armamentarium.[8] It should be attempted within 2 hours after the onset to avoid long-term sequelae.[9,10] When performed, it allows the septum and anterior lamella of lower eyelid to move anteriorly therefore decompressing the orbital compartment.[5] If the lesion continues to expand after surgery, the procedure provides only temporary relief and further interventions such as orbitotomy should be planned should a rise in orbital pressure recur.[9] Given that bony orbital decompression is an effective treatment for OCS,[11] it was the theoretical adage that displaced orbital fractures should prevent its occurrence by allowing the hemorrhage to drain into the maxillary sinus antrum.[12] However, in rare cases, OCS occurs despite a displaced orbital fracture. The knowledge of pathophysiology and management of OCS in such a situation remains a clearly unmet need and consists only of case reports and case series in the published literature.

The aim of the current review is to present the pathophysiology of OCS despite displaced orbital fractures, and to present its management based on what is published in the medical literature, and our center's experience.

Materials and Methods

A systematic review of literature was conducted using the PubMed, Medline, Embase, and Cochrane databases, from inception through February 1st, 2021. The following search query was used: "Orbital fracture" and "Trauma" and "Orbital Compartment Syndrome." Included studies were those who described an acute OCS despite displaced orbital fractures, and the diagnosis and treatment undertaken. During literature search and given the paucity of literature studies regarding the subject matter, cohort studies, case series, and case reports were all included. Non-English language articles were excluded. Included articles' bibliographies were searched for any other eligible missing articles. Out of 116 articles, only eight studies were selected based on whole manuscript reading (►**Table 1**).[3,9–11,13–16] We also describe two cases that presented to our trauma center after facial blunt-type trauma with displaced orbital fractures and concomitant OCS that required emergent lateral canthotomy (►**Table 1**).

Results and Discussion

Nearly all studies discussing OCS despite orbital fracture were included in the study, and 18 patients who had concurrent orbital fractures and OCS were studied. The mean cohort age was 49.3 ± 30.6 years old, female-to-male ratio was 1:1,

Table 1 Main results of studies included in our review

Reference	Study design	LOE	Patients (Included)	Orbital fracture type	Treatment	Visual recovery
Gerbino et al (2005)	Case series	IV	8 (6)	4 OZC	SPD (2 ST, 1 SP, 1 P)	3 Complete,
						1 Absent
				MW	SPD (ST)	Partial
				OR	SPD + M (C)	Partial
Goodall et al (1999)	Case series	IV	5 (1)	OZC	ILC + C	Complete
Gupta and Beigi (2017)	Case report	IV	1 (1)	OF + MW	ILC + C	Complete
Kitaguchi et al (2019)	Case series	IV	4 (1)	OF + MW	ILC + C ◊ BMWD	Complete
Kondoff et al (2019)	Case series	IV	94 (1)	N/R	ILC + C	Complete
Larsen and Wieslander (1999)	Case report	IV	1 (1)	LW	ILC + C	Complete
Schwitkis et al (2018)	Case report	IV	1 (1)	MW	ILC + C	Complete
Sun et al (2014)	Case series	IV	8 (6)	MW + OZC	ILC + C	Partial
				OF + MW + LW + OZC	CLC + C	Complete
				OF + MW	CLC + C	Complete
				OF + Lefort II + Lefort III	ILC + C	Partial
				OF + LW + Lefort III	CLC + C	Partial
				OF	ILC + C	Partial

Abbreviations: BMWD, bony medial wall decompression; C, coronal; CLC + C, complete lateral canthotomy + cantholysis; ILC + C, inferolateral canthotomy + cantholysis; LW, lateral wall; M, myringotomy; MW, medial wall; N/R, not reported; OFB, orbital floor; OR, orbital roof; OZC, orbitozygomatic complex; P, palpebral; SP, supra-palpebral; SPD, subperiosteal drainage; ST, subtarsal.
Note: The number between parentheses represents the number of orbital compartment syndrome (OCS), therefore the number of patients included in the study.

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Table 2 Clinical presentation of displaced orbital fractures with orbital compartment syndrome

Clinical presentation	Incidence (%)	Patients (*n*)
Loss of VA	94.4	17
RAPD	77.8	14
Periorbital edema	61.1	11
Proptosis	61.1	11
Ophthalmoparesis	50	9
Chemosis	38.9	7
Tense orbit	22.2	4
Hyphema	5.6	1

Abbreviations: RAPD, relative afferent pupillary defect; VA, visual acuity.

38.9% (7/18) were physically assaulted, 27.8% (5/18) had a mechanical fall, 22.2% (4/18) had a motor vehicle collision, and 5.6% (1/18) had a sports accident. All patients had a displaced fracture of $\geq$1 orbital wall. Nine (50%) patients presented with a medial orbital wall fracture, seven (38.9%) with orbital blowout fracture, five (27.8%) with a lateral orbital wall fracture, five (27.8%) had an orbital-zygomatic complex fracture, and one (5.6%) had an orbital roof fracture. Clinical presentation of patients is presented in ►**Table 2**.

Pathophysiology

Traumatic OCS is a rare complication of facial trauma. It occurs in 2 to 5% patients with acute orbital trauma,[17] but constitutes the most common cause of blindness in this setting,[18] with trauma accounting for 45% of all cases.[5,10] Theoretically, orbital fractures increase orbital volume and provide an egress for the retrobulbar hematoma into the maxillary sinus or nasal cavity, therefore giving a false sense of relief protecting against OCS (orbitotomy and deliberate orbital wall fracture are recommended therapeutic measures in the case of a failed resolution of OCS with canthotomy and cantholysis).[13,19,20] We now know that OCS occurs with or without orbital fractures.[13] A possible explanation behind this lies in the presence of Koorneef's fibrous septa dividing the orbital fat into several compartments,[20,21] and the possible "plugging" of the orbital floor by the inferior rectus or sinus mucosa. However, orbital fractures more likely cause extraconal hematomas which in this study is the most common cause of compartment syndrome (60% extraconal, 20% combined intraconal and extraconal).

History, Physical Examination, and Paraclinical Studies

The clinical diagnosis of OCS consists of proptosis (100%), periorbital edema (100%), loss of VA (100%), relative afferent pupillary defect (RAPD) (80%), ophthalmoparesis (80%), and chemosis (70%) as the most common signs and symptoms.[10] The absence of RAPD is not a conclusive sign of the absence of OCS as it is a "lagging" sign of optic nerve dysfunction as perfusion has already been compromised.[13] The diagnosis of fracture/compartment syndrome can be made tentatively,[13] even without a clear-cut ophthalmology examination. Optic disk edema and central retinal artery pulsations can also be found on fundoscopy,[10] but are often inconstant signs. Physicians should not rule out the diagnosis before recording at least one visual acuity (VA) and requesting an ophthalmology consult in the emergency department.[22] However, Gupta et al[13] argued that VA requires cooperation of the patient and requires an intact eye function otherwise, as it may be affected by periocular edema, chemosis, lens trauma or vitreous hemorrhage.

Posterior tenting of the globe (posterior angle $<$120 degrees on CT imaging of the orbits) with acute proptosis was found in 33.3% (6/18) of cases in our study (with an average of 107 degrees) and this combination of signs is associated with a poor prognosis,[23] therefore, its absence (5/18 patients, 27.8%), does not preclude a cantholysis and inferior-lateral canthotomy which should be attempted because its benefits outweigh its risks.[1,13] Prompt treatment should not be delayed by fundoscopic, paraclinical exams and imaging modalities.[1,13]

Management

Medical management of an OCS includes bed rest, head of bed elevation, ice packs, avoidance of straining, acetazolamide 500 mg PO, or IV methylprednisolone 30 mg/kg bolus then 5.4 mg/kg/h/24 h continued PO 250 mg/12 h, IV mannitol, and treatment of an underlying hypertensive episode or coagulation disorder.[5] However, a medical treatment should only be undertaken in mild cases without VA deterioration as the exact efficacy of these agents is uncertain and any change in VA, symptoms, or regular IOP exams should prompt emergent surgical treatment.[1,5]

Surgical decompression of an OCS remains the mainstay of treatment.[1,5] In this review, inferior-lateral canthotomy and cantholysis were performed in 50% (9/18) of cases and complete lateral cantholysis (release of the inferior and superior limbs of the lateral canthal ligament with a septal release) was needed in 16.7% (3/18) of cases while a bony medial wall decompression was added in 5.6% (1/18) of cases in the case of a persistent elevated IOP 7 hours after an inferior-lateral canthotomy. Additional treatment modalities included a subperiosteal drainage with myringotomy via suprapalpebral or coronal approach in 22.2% (4.18) of patients and subperiosteal drainage via a subtarsal approach in 16.7% (3/18) of patients. Lateral canthotomy and cantholysis are more effective than canthotomy or cantholysis alone, therefore, must be used consistently.[24] If this fails to relieve the pressure, a superior lateral canthotomy is also performed, releasing the superior limb of the lateral canthal ligament. If intraocular pressure (IOP) and/or symptoms persist, a septal release is undertaken via the lateral canthotomy or medial wall orbital decompression may be used.[5,11,20] Two cadaveric study showed that a septal release (also called septal release) performed before or after an inferior-lateral canthotomy and cantholysis further reduces IOP.[25,26] In our constituted cohort (11 patients included), pre-procedural intra-ocular pressure (IOP) was 56.6 ± 10.2 mm Hg and post-procedural IOP was 20.3 ± 7 mm Hg. A Chi-square with a McNemar's test revealed

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a statistically significant difference in IOP before and after lateral canthotomy and cantholysis performed in patients with OCS and displaced orbital fractures (X2 [1, $N = 10$] = 16.6, p-value = 0.00005). Mean pre-procedural VA was 0.0875 (Snellen 6/75) and mean post-procedural VA was 0.67 (Snellen 6/9.5) but there was no statistically significant difference found (p-value 0.63).

Recovery after cantholysis is not always immediate, with up to 4 weeks of ongoing improvement in VA.[3,27,28] Patients treated after 2 hours will have poor outcomes and 25% of patients have a Snellen VA of >6/12 versus 85% of patients treated before 2 hours.[1] In this review, the mean time of decompression (all methods included) was 2.67 ± 2.12 hours (we excluded the 7 hours delay before attempting bony decompression after a failed inferior-lateral canthotomy and cantholysis) with 61.1% (11/18) of patients having a complete recovery, 33.3% (6/18) partial recovery, and 5.6% (1/18) of patients with no VA recovery. Therefore, fast decision-making and minimizing delays with unnecessary imaging and diagnostic studies cannot be over-emphasized to stay under the 90 to 120 minutes limit.[29]

Additional Cases from Our Center

Given the paucity of cases reported in the literature, we add to the previously constituted cohort two cases of a 27-year-old male and 49-year-old female with concurrent orbital fractures and OCS, who presented to our tertiary care center.

The first patient suffered a projectile blunt-type trauma to the right orbit. He presented within 60 minutes with severe peri-ocular facial and nasal ecchymosis and edema, mild proptosis of right eye. Physical examination showed no light perception, severe chemosis, subconjunctival hemorrhage, tight lid edema, limitation of upgaze and adduction, accompanied by a severe throbbing pain in his eye, and an RAPD. Step-off deformity and pain were noted on palpation over the inferior, medial orbital rim and nasal bones. An inferior lateral canthotomy and cantholysis was performed under local anesthesia in the emergency department and the wounds packed allowing for soft tissue decompression. A computed tomography scan showed an orbital blowout fracture with inferior rectus entrapment, a type I (Markowitz and Manson) naso-orbito-ethmoidal fracture and multiple hyperdense stranding of the retrobulbar fat with stretching of the optic nerve (►**Fig. 1A** and **B**). Post-procedural examination showed an improvement of VA to hand motion and a reduction in IOP taken by bi-digital tonometry. VA at 5 minutes was 20/100. The patient was admitted for clinical surveillance and VA checked each hour. Final examination at 1 week with VA at 20/80 showed an iris contusion, anterior chamber reaction, and a macular hole seen after clearance of vitreous hemorrhage. IOP by applanation tonometry was14 mm Hg.

The second patient was admitted 30 minutes following a tertiary blast-type injury after an explosion with a decreased level of consciousness (GCS = 12), multiple facial lacerations, and bilateral orbital ecchymosis. She exhibited bilateral proptosis with tight eyelids, severe chemosis, and a sudden loss of VA (no light perception) bilaterally. Bilateral

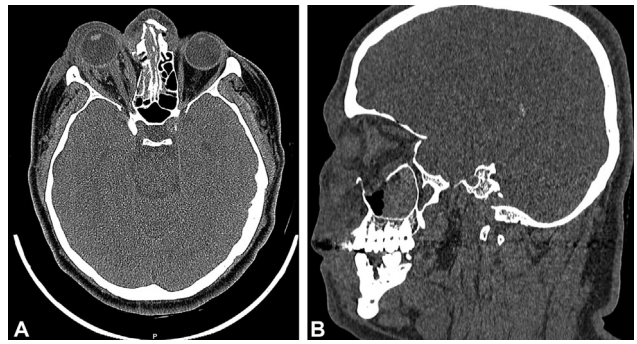

Fig. 1 Computed tomography (CT) scans of the first patient. (**A**) Axial CT scan showing the right naso-orbito-ethmoidal fracture, hyperdense stranding of retro-orbital fat, and stretching of the optic nerve. (**B**) Sagittal CT scan showing the right type III orbital floor fracture with a retrobulbar hematoma and probable incarceration of the inferior rectus muscle.

emergent infero-lateral canthotomy and cantholysis were performed in the ED triage area (following MCI protocols). A cerebral-facial CT scan was found to have a left acute subdural hematoma and right epidural hematoma, bilateral blowout orbital floors, and displaced medial and lateral walls, along with bilateral retrobulbar hematomas and stretching of the optic nerves. She was sent to the OR for an emergent craniotomy after a reduction in GCS to 10. An IOP was taken by tonometry before induction (30 minutes from the first canthotomy and cantholysis) and was found to be elevated at 50 mm Hg (OD) and 52 mm Hg (OS) so bilateral superior-lateral canthotomy and cantholysis were performed as the neurosurgery team scrubbed. IOP mid-craniotomy with tonometry was 17 mm Hg (OD) and 19 mm Hg (OS) and was then checked each hour after. Awake post-procedural examination showed an improvement of VA to hand motion perception and a reduction in IOP of 15 mm Hg, and VA was 20/80. Slit-lamp examination only showed bilateral iris contusions. In our cases, a clear clinical diagnosis of OCS was difficult to confirm because of the iris contusion and the vitreous hemorrhage precluding the evaluation of an eventual RAPD or optic disk edema. The patients' VA clearly improved after cantholysis which confirmed the contribution of the OCS to the deterioration of visual function.

Differential diagnosis to consider include an orbital apex syndrome and a carotid-cavernous fistula which could be associated with an orbital hemorrhage, but no case reports have been described.[13] Furthermore, traumatic optic neuropathy (stretch or transection) must be ruled out.[30]

Limitations of this study include a small number of patients reported. However, OCS despite orbital fracture is considered as an extremely rare condition, limiting therefore sufficient data until now. Although treatment modality success rates cannot be compared, using any of the techniques reported resulted in at least a partial VA recovery if attempted within the recommended timeline. Other limitations were inter-practitioner disparities, and a publication bias as only published articles were included.

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Conclusion

Although exceedingly rare, OCS can occur with displaced fractures of the orbital cavity. This often-confusing clinical presentation should not discount the presence of a sight-threatening emergency and should prompt an emergent canthotomy and inferior-lateral cantholysis with the shortest delays in diagnostic and imaging studies as clinically possible.

Patient Consent
Both patients have signed a written informed consent form to the inclusion of material pertaining to themselves. They acknowledge that they cannot be identified via the paper, and that they are fully anonymized.

Funding
None.

Conflict of Interest
None declared.

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